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DO ENVIRONMENTAL PROVISIONS IN PREFERENTIAL TRADE AGREEMENTS REDUCE EMISSIONS TRADED IN GLOBAL VALUE CHAINS?

Maisha Fairuz and Neil Foster-McGregor

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ABSTRACT

While global value chains (GVCs) are considered an important development escalator, concerns over their environmental consequences have been increasing. By providing opportunities to shift production to developing economies, GVCs risk carbon leakage. Preferential trade agreements (PTAs) have proved important drivers of GVC trade. In this paper we examine whether the presence and breadth of PTAs is associated with increased emissions embodied in GVC trade, and further ask whether the presence of environmental provisions in PTAs impacts upon emissions traded in GVCs. Our results suggest that the presence of a PTA between partners is associated with increased emissions embodied in GVC trade, with this effect largely the result of increased GVC trade between PTA partners. We also show, however, that the presence of an environmental provision in PTAs can mitigate this effect, with environmental provisions reducing both the scale of GVC trade and the emissions intensity of that trade.

Keywords: global value chains, CO₂ emissions, preferential trade agreements, gravity model

JEL codes: F13, F18, Q56

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1. INTRODUCTION

Global value chains (GVCs) have become a critical part of the global trade network, driving economic development and industrialization by enabling economies to specialize in specific stages of production rather than entire industries (Bank 2019; Taglioni and Winkler 2016). This fragmentation of production has provided developing economies in particular with a more accessible path to industrialization (Baldwin 2018). However, alongside economic benefits, GVCs have been linked to a growing share of global CO₂ emissions. Carbon-intensive production stages, such as intermediate manufacturing, can be offshored to economies with weaker environmental protection, resulting in relocation rather than a reduction in global CO₂ emissions (Peters et al. 2011). With this offshoring often taking place from developed to developing economies that have weaker environmental standards and are more emissions intensive in production, this carbon leakage can result in higher emissions overall. Whereas the evidence of carbon leakage remains weak, the possibility raises questions regarding trade liberalization policies and the resulting environmental footprint (Antweiler, Copeland, and Taylor 2001; Dean 2002; Lopez 2017).

Over the past few decades, preferential trade agreements (PTAs) have facilitated trade liberalization, which has in turn promoted a deeper integration of economies into GVCs (Delera and Foster-McGregor 2020). Simultaneously, PTAs have evolved to encompass broader issues (Mattoo, Rocha, and Ruta 2020), including environmental provisions aimed at mitigating the environmental impacts of trade. The central question is whether PTAs, by promoting GVC trade, contribute to higher CO₂ emissions, and if inclusion of environmental provisions within these agreements can effectively reduce emissions or emissions intensity.

From a theoretical perspective, GVCs influence the CO₂ emissions of an economy through three primary channels. First, a scale effect results from the expected positive impact of GVCs on productivity and production, resulting in higher emissions produced (Antweiler, Copeland, and Taylor; Wang, Wan, and Wang 2019). Second, GVCs may alter the composition of production, often shifting it toward more emissions-intensive manufacturing sectors, especially in developing economies. However, the relationship between GVC participation and emissions per capita may be nonlinear as a high enough participation rate may have a negative influence on emissions (Wang, Wan, and Wang 2019). This is the structure effect, whereby GVCs change the composition of productive activities within an economy, resulting in changes in the economy's emissions profile. Third, the technology effect suggests that GVC participation can lead to the diffusion of cleaner technologies, potentially reducing the carbon intensity of production (Delera et al. 2022; Gries et al. 2018).

PTAs, particularly those with strong environmental provisions, can impact all three of these channels. While PTAs promote GVC trade, they can also influence the structure of production and encourage technology sharing through regulatory harmonization and

cross-border investments. Nevertheless, the presence of environmental provisions within PTAs further confounds these expected effects. For instance, environmental provisions that are restrictive may have a negative effect on trade, ultimately leading to a negative scale effect through PTAs. Moreover, the role of legal enforceability of these provisions remains underexplored within a GVC context. Finally, such changes in PTA design also raise questions of how costs and benefits from such agreements are distributed among members of different income levels.

Using GVC data from the EORA multiregional input-output tables (Lenzen et al. 2012, 2013) and PTA data from Hofmann, Osnago, and Ruta (2017), we study the effect of PTAs, particularly PTA breadth and the presence of environmental provisions, on CO₂ emissions embodied in GVC trade. While PTAs are expected to increase emissions through the scale effect, the existence of environmental provisions may mitigate this. We find that PTAs do increase CO₂ emissions in GVCs. However, the presence of environmental provisions offsets most of the increase in GVC-related emissions, most likely through trade restrictive clauses. Our results indicate that environmental provisions reduce GVC emissions through the structure and technology effect. In addition, we explore whether legal enforceability of these environmental provisions makes them more effective in reducing emissions in GVC trade. We find that both enforceable and nonenforceable environmental provisions have negative effects on emissions traded in GVCs, finding in some cases that non-enforceable provisions are more effective. Finally, we assess whether the effects of environmental provisions and PTAs in general for environmental consequences differ based on the income level of the economies. We find that the scale effect predominates in low, upper-middle and high-income economies, but the intensity effect (i.e., structure and technology effects) is more pronounced in lowermiddle income economies.

The following section reviews the literature on the role of GVCs in global emissions and the effect of PTAs in driving trade. It also reviews literature on the consequences of increasing the breadth of PTAs, especially the environmental provisions. Section 3 outlines the econometric specification in relation to the scale, structure, and technology effects, and describes the construction of indicators of CO₂ emissions embodied in GVC trade. Section 4 presents the results and section 5 provides a discussion and conclusion.

2. LITERATURE REVIEW

Impact of GVC Trade on CO₂ Emissions

GVCs involve the fragmentation of production processes across multiple economies, a trend which has dramatically reshaped the global economy and trade dynamics. Their environmental implications, particularly regarding CO2 emissions, have been studied from both the production and consumption perspective, and tied to ecologically unequal exchange (Althouse et al. 2023; Meng et al. 2018; Moran et al. 2013; Wang, He, and Song 2021). GVCs account for an increasing share of CO₂ emissions and present the risk of carbon leakage, with carbon intensive stages of production moving to economies with weak environmental protection and relatively emissions intensive production processes.¹ High-income economies may outsource pollution-intensive production processes to lower-income economies, effectively transferring the emissions burden while reaping the benefits of clean final production (Kanemoto et al. 2012). This phenomenon, termed "carbon leakage," potentially exacerbates the environmental impact of GVCs as reductions in emissions in one economy can be offset by increases in another (Babiker 2005). Although the evidence in favor of carbon leakage is rather weak (Grubb et al. 2022), the potential for carbon leakage is one argument put forward to support the introduction of the European Union's Carbon Border Adjustment Mechanism (CBAM) (Nordström 2023) and remains a concern as carbon prices being to rise and carbon pricing is introduced in more jurisdictions (Black, Parry, and Zhunussova 2022).

As mentioned, GVCs can affect CO₂ emissions through three main channels. The scale effect occurs when GVCs result in increased production, which in turn increases overall emissions (Al-Mulali and Sheau-Ting 2014; Weber et al. 2008). The structure effect involves GVCs shifting production toward dirty sectors, usually in manufacturing, which results in more carbon-intensive production (Guo, Zou, and Wei 2010; Kumbaroğlu 2011; Stöllinger 2016; Zhao et al. 2017). Finally, the technology effect considers GVCs as a source of technological change that can reduce CO₂ emissions and emissions intensities (Morrison, Pietrobelli, and Rabellotti 2008; Okushima and Tamura 2010; Wang, He, and Song 2021; Zhang et al. 2021). Given these channels, there is an expectation that the scale and structure effect of GVCs works to increase CO₂ emissions embodied in GVC trade, while the technology effect decreases emissions.

The Role of PTAs in Driving GVC Trade and Increasing Breadth of PTAs

The proliferation of PTAs has been a crucial driver of GVC expansion by promoting trade liberalization and reducing barriers to trade. PTAs facilitate the cross-border movement of goods and services, particularly intermediate goods, which are central to GVCs. This is achieved through tariff reductions, harmonization of standards, and investment protections that enhance trade flows between member economies (Baldwin 2013). Moreover, the design of PTAs can influence the extent to which they promote GVC integration. The horizontal depth or breadth of a PTA—measured by the

¹ This alludes to the pollution haven hypothesis, which is explored later in the literature review.

comprehensiveness of its provisions, such as the inclusion of investment rules, intellectual property rights, and dispute settlement mechanisms—has been shown to correlate positively with GVC trade (Boffa, Jansen, and Solleder 2019; Delera and Foster-McGregor 2020; Laget et al. 2020).

The expansion of PTAs beyond traditional trade liberalization reflects the growing recognition that trade agreements must also address the environmental challenges posed by increased global economic integration. While early PTAs primarily focused on tariff reductions and market access, more recent agreements have included environmental provisions to ensure that trade does not come at the cost of environmental degradation. These provisions are designed to harmonize environmental standards across signatory economies, promoting sustainable development and reducing the risk of negative externalities, such as pollution from GVCs (Morin, Dür, and Lechner 2018). The inclusion of environmental provisions is now seen as essential to ensuring that trade liberalization supports not only economic growth but also environmental protection, particularly in industries deeply integrated into GVCs. In theory, this shift in PTA design should have an impact on CO₂ emissions in GVC trade, as environmental provisions impose commitments on member economies to uphold environmental standards, adopt cleaner technologies, and reduce emissions embodied in trade flows (Martínez-Zarzoso and Oueslati 2018).

These trends further highlight the dual role of PTAs with environmental provisions. PTAs, by reducing trade barriers, are expected to increase trade among members which, in turn, increases emissions. This positive correlation between trade and emissions is well documented in empirical literature. At the same time, environmental provisions in PTAs can offset this increase in emissions through a change in structure of trade or technology transfer that allows cleaner production and trade.

The Rise of Environmental Provisions in PTAs

Brandi et al. (2020) argue that environmental provisions within PTAs affect trade through both trade restrictive and liberal mechanisms. Restrictive environmental provisions are designed to limit carbon-intensive trade flows either through stringent regulations on environmental standards or through restricting trade in 'dirty' goods. Liberal environmental provisions, on the other hand, are geared toward facilitating 'green' trade through reductions in trade barriers in environmental goods and facilitating the adoption of clean technologies or promoting eco-friendly trade practices, which may enhance competitiveness by driving innovation and efficiency—a premise consistent with the Porter Hypothesis (Porter 1991; Porter and van der Linde 1995). According to the Porter Hypothesis, well-designed environmental regulations can stimulate innovation, leading to "win-win" outcomes where both environmental quality and economic performance improve (Mealy and Teytelboym 2022). This is analogous to the technology effect outlined earlier.

While environmental provisions garner public support, some studies argue that they can be used as a bargaining tool in trade agreement negotiations as well as a mechanism to restrict the competitiveness of those economies with the fewest environmental regulations. Environmental provisions essentially increase the number of issue areas that can be negotiated, increasing the potential trade-offs and the bargaining power of some members (Brandi et al. 2022; Johnson 2015). This is also tied to the economic rationale behind environmental provisions, whereby economies with stringent environmental regulations may seek to "level the playing field" through urging the uptake of environmental provisions so that members with weaker environmental regulations lose their cost competitiveness (Blümer et al. 2020; Brandi et al. 2020). By this logic, environmental provisions in PTAs function as tools to further green protectionism (Bechtel, Bernauer, and Meyer 2012; Ederington and Minier 2003).

Studies on emissions convergence among PTA members also lend some support to the idea of environmental provisions creating equal conditions. Zhou, Tian, and Zhou (2017) find that regional trade agreements with environmental provisions lead to convergence in emissions of particulate matter, whereas agreements without provisions increase concentrations of particulate matter. Baghdadi, Martínez-Zarzoso, and Zitouna (2013) identify trade agreements with environmental provisions as being a driver of convergence in CO₂ emissions between economy-pairs. However, this pattern of emissions convergence raises doubts on who bears the environmental burden. As studies have shown convergence at lower levels, it is more likely that low-income countries with weaker environmental performance carry the bulk of environmental responsibility, a notion closely tied to the pollution haven hypothesis. Kolcava, Nguyen, and Bernauer (2019) find partial evidence that trade liberalization through PTAs leads to environmental burden shifting to low-income countries. They further reiterate the role of domestic institutions and technology transfer through cross-border trading in limiting the burden shifting.

The adoption of environmental provisions has profound implications for domestic regulatory bodies. Legally enforceable environmental clauses hold signatory economies accountable for environmental commitments, often providing mechanisms such as sanctions or dispute settlement processes for non-compliance. This legally enforceable nature differentiates them from soft law provisions, which may simply encourage good practices without holding economies accountable for lapses in compliance. Martínez-Zarzoso and Oueslati (2018) find that provisions that are legally binding led to a faster CO₂ convergence than those that are not. While studying domestic implementation of commitments in international environmental treaties and PTAs, Brandi et al. (2019) find that member economies are more likely to implement regulations under PTAs which tend to be able to be more stringently enforced. Legal enforceability of environmental provisions is seen as essential for change in domestic environmental laws (Meinhart 2022). Studies have also shown that the US and EU are critical players in pushing for stringent and enforceable provisions in PTA design (Bastiaens and Postnikov 2017; Horn et al. 2010; Jinnah and Lindsay 2016). However, this leaves out the question of whether the legal enforcement of environmental provisions is more effective in practice.

These studies highlight the role of bargaining power dynamics between high and lowincome countries in PTAs. Stringent environmental provisions, which may significantly exceed the current regulatory standards in low-income countries, can lead to profound changes in production processes, as these economies are forced to meet higher standards. This may have a large negative impact on their emissions embodied in trade. However, high income economies are better equipped to benefit from the integration of environmental provisions due to their access to advanced technologies and greater financial resources, as well as preexisting regulatory institutions. This discrepancy in capacity may lead to uneven outcomes in PTAs. Furthermore, the absolute level of emissions from low-income countries is relatively small, but their gains from trade are critical for their development. In other words, the cost of restrictive environmental provisions may be disproportionately distributed between low- and high-income economies.

Addressing Gaps in the Literature

While PTAs have been shown to be effective drivers of GVC trade, empirical studies have yet to uncover the effectiveness of environmental provisions in terms of reducing CO2 emissions embodied in GVCs. Furthermore, the effectiveness of legal enforceability of environmental provisions remains unexplored from a GVC perspective. Non-binding provisions can promote voluntary cooperation, technology transfer, and capacity building without imposing strict compliance costs that could disadvantage lower-income economies or hinder trade integration (Downs, Rocke, and Barsoom 1996; Milewicz et al. 2018; Morin, Dür, and Lechner. 2018; Sprinz and Vaahtoranta 1994). In GVC trade, where production is geographically dispersed, such flexibility can encourage gradual improvements in environmental standards and incentivize multinational firms to adopt sustainable practices without the immediate threat of penalties. In addition, the income level of economies may play a role in shaping the effectiveness of these provisions. Highincome economies, with better access to green technologies and regulatory capacity, are more likely to benefit from environmental provisions, whereas low-income countries may struggle to comply because of resource limitations. As a result, provisions that offer flexibility rather than strict enforcement may be particularly advantageous for lowerincome economies, allowing them to gradually enhance their environmental performance without disrupting their trade integration. This approach aligns with the Porter Hypothesis, which suggests that flexible, innovation-driven regulations can enhance both competitiveness and environmental performance (Porter and van der Linde 1995).

3. METHODOLOGY

To examine the impact of the presence and breadth of a PTA and the presence of environmental provisions in these PTAs on emissions embodied in bilateral GVC trade we adopt the familiar gravity model. The basic regression for the structural gravity model is thus:

$$\ln GVCem_{ijt} = \beta_1 PTA_{ijt} + \beta_2 EnvProv_{ijt} + \alpha_{ij} + \gamma_{it} + \delta_{jt} + \varepsilon_{ijt}$$
(1)

Where i, j, and t denote exporter, importer, and time, GVCem refers to emissions in GVC trade, PTA captures either the presence (i.e., a dummy variable) or the breadth of PTAs, and EnvProv is a dummy capturing whether the PTA has an environmental provision or not. Following recent literature using the structural gravity model, the regression model

further includes economy-pair fixed effects to help solve issues of endogeneity and importer-time and exporter-time fixed effects to control for multilateral resistance (Anderson and van Wincoop 2003).

Beyond considering the overall effect of PTA presence and environmental provisions on emissions embodied in GVC trade, we are further interested in understanding the channels through which any effect works. As discussed, PTAs can impact upon emissions embodied in GVC trade through a scale effect and through effects working on the structure of GVC trade and technology, both of which would be expected to impact on aggregate emissions intensity in GVC trade. As such, we decompose overall emissions in GVC trade and an intensity effect using the following:

$$GVCem_{ijt} = GVCexp_{ijt} \times \frac{GVCem_{ijt}}{GVCexp_{iit}}$$

Where *GVCexp* refers to the value-added that is exported in GVCs. We then re-estimate the structural gravity model using the two terms on the right-hand side as dependent variables:

$$\ln GVCexp_{ijt} = \beta_1^1 PTA_{ijt} + \beta_2^1 EnvProv_{ijt} + \alpha_{ij} + \gamma_{it} + \delta_{jt} + \varepsilon_{ijt}$$
(2)

$$\ln\left(\frac{{}_{GVCem_{ijt}}}{{}_{GVCexp_{ijt}}}\right) = \beta_1^2 PTA_{ijt} + \beta_2^2 EnvProv_{ijt} + \alpha_{ij} + \gamma_{it} + \delta_{jt} + \varepsilon_{ijt}$$
(3)

Given the linear nature of the fixed-effects panel regression, the estimated coefficients from these two regression models will sum up to the estimated coefficients in equation (1) (i.e., $\beta_1 = \beta_1^1 + \beta_1^2$ and $\beta_2 = \beta_2^1 + \beta_2^2$), allowing us to decompose the overall effect of PTAs and environmental provisions into a scale and intensity effect.

To proceed, we further need to construct indicators of the emissions that are embodied in GVC exports. To do this, we build upon the decomposition of value-added of Wang, Wei, and Zhu (2017). That paper decomposes the value-added of a sector and economy into three terms: (i) value-added embodied in domestic production that serves domestic consumption; (ii) domestic value-added embodied in final goods exports (traditional trade); and (iii) value-added embodied in exports of intermediates that are used for either final production and consumption in the importing economy or further processing and exporting (GVC trade). Wang, Wei, and Zhu (2017) further split the GVC component into two terms, one capturing simple GVC activities that involves value-added crossing borders just once—i.e., that is used by a direct importing economy to produce products that are absorbed in that economy, and one capturing complex GVC activities that involve value-added crossing borders at least twice, i.e., value-added that is embodied in intermediate goods that are used by a partner to produce exports (either intermediate or final).

The starting point for the decomposition is a standard multiregional input-output framework. We begin by assuming that there are N economies and S industries in each

economy, with industry output in an economy produced using domestic production factors (i.e., capital and labor) and intermediate inputs, which can be sourced domestically or from foreign sources. The output produced in each industry can be used as either final demand or as intermediate inputs used in the production of other goods, either domestically or abroad. When considering shipments of final goods and intermediates both within and across economies, we need to distinguish between the source and destination economy-industry. We use *i* to denote the source economy, *j* the destination economy, *k* the source industry and *l* the destination industry.

Following Wang, Wei, and Zhu (2017), we define Z^{ij} as an $S \times S$ matrix of intermediate flows produced in economy *i* and used in economy *j*, Y^{ij} as an $S \times 1$ vector of final products produced in economy *i* and consumed in economy *j*, and X^i as an $S \times 1$ vector of gross outputs in economy *i*. We further define the input coefficient matrix as $A = Z\hat{X}^{-1}$, where \hat{X} denotes a diagonal matrix with the output vector in its diagonal. Using these, we can write gross output in matrix form as:

$$X = AX + Y \tag{4}$$

Where the first term on the right of the equation represents intermediate products and the second term final products. Following Leontief (1936), this can be rewritten as:

$$X = BY \tag{5}$$

Where $B = (I - A)^{-1}$ is the well-known (global) Leontief inverse.

One of the contributions of Wang, Wei, and Zhu (2017) is to rewrite equation (A1) as:

$$X = AX + Y = A^{D}X + Y^{D} + A^{F}X + Y^{F} = A^{D}X + Y^{D} + E$$
 (6)

Where A^F is an $SN \times SN$ off-diagonal block matrix of imported intermediate input coefficients, $A^D = A - A^F$, *Y* is an $SN \times 1$ vector of final products, Y^D is an $SN \times 1$ vector of final products for domestic consumption, $Y^F = Y - Y^D$, and *E* is an $SN \times 1$ vector of gross exports.

Rearranging this equation, Wang, Wei, and Zhu (2017) express gross output as:

$$X = (I - A^{D})^{-1}Y^{D} + (I - A^{D})^{-1}E = LY^{D} + LE$$

$$X = LY^{D} + LY^{F} + LA^{F}X$$

$$X = LY^{D} + LY^{F} + LA^{F}BY$$
(7)

Where $L = (I - A^D)^{-1}$ is the local Leontief matrix, an $SN \times SN$ block diagonal matrix. In their analysis, Wang, Wei, and Zhu (2017) diagonalize the *Y* matrices and pre-multiply each of the three terms of equation (7) by a diagonalized $SN \times 1$ matrix of value-added to gross output to decompose domestic value-added generated or foreign value-added used in the production of final products, with the three terms capturing: (i) value-added that is domestically produced and consumed; (ii) value-added that is embodied in final product

exports (i.e., crosses national borders for consumption only); and (iii) value-added that is embodied in intermediate goods exports (considered to capture GVC trade).

To construct indicators of the CO₂ emissions embodied in GVCs, we adapt this approach, replacing the $SN \times 1$ vector of value-added to gross output with a (diagonalized) $SN \times 1$ vector of CO₂ emissions to gross output. A typical element in this vector, c^{ki} , gives the amount of CO₂ emissions in sector *k* of economy *i* per unit of gross output. Defining *C* as the $SN \times 1$ vector of CO₂ emissions to gross to gross output, we can write the expression decomposing CO₂ emissions as:

$$\hat{C}BY = \hat{C}L\hat{Y}^D + \hat{C}L\hat{Y}^F + \hat{C}LA^F B\hat{Y}$$
(8)

Where a hat over a variable indicates a diagonalized vector. The three terms on the RHS are matrices of dimension $SN \times SN$ and capture:

- 1. $\hat{C}LY^D$ CO₂ emissions that are both domestically produced and domestically consumed (i.e., embodied in products produced and consumed within an economy).
- 2. $\hat{C}LY^F$ CO₂ emissions embodied in the final products of an economy that are subsequently exported.
- 3. $\hat{C}LA^FBY CO_2$ emissions embodied in the intermediate goods of an economy that are subsequently exported for further processing or create final production.

In our analysis, our focus is on the third of these terms, which is considered to capture the emissions embodied in GVC trade. The resulting $SN \times SN$ matrix of this latter term can be considered in two ways. Considering the columns of this matrix allows one to calculate estimates of the emissions that an economy receives from other economies through GVC trade, while a row perspective allows for the calculation of the emissions that an economy exports that are embodied in intermediates to other economies. Receiving emissions are often termed as coming from the consumption perspective, whereas exporting emissions are from the production perspective. Our interest is in the effect of PTAs and environmental provisions on the export of emissions embodied in GVCs, and as such we adopt the production perspective, calculating the row sum of emissions in GVC trade by partner.

4. DATA AND DESCRIPTIVE ANALYSIS

The main data used to construct emissions in GVCs is the EORA multiregional inputoutput database (Lenzen et al. 2012, 2013). EORA comprises a multiregional input-output database for 1990–2016, 26 sectors, and 190 economies. In addition, EORA includes a set of satellite accounts, including estimates of CO_2 emissions emitted in each sector during production.

The PTA data come from Hofmann, Osnago, and Ruta (2017) and include information on 279 trade agreements signed by 189 economies over 1958–2015. Besides the presence of a PTA, the data set includes information on whether the agreements include a set of

52 PTA provisions (including environmental provisions), further distinguishing between provisions that are legally enforceable and those that are not.

Figure 1 reports the growth in the number of PTAs and environmental provisions within them. The cumulative number of PTAs grew steadily from 13 in 1990 to 217 in 2016. The orange line in the figure shows the share of PTAs that have environmental provisions PTAs, with this share increasing from 23% in 1990 to 45% in 2016. The increase in the share of PTAs with environmental provisions in the early 1990s likely reflects a couple of developments. One was the development and expansion of trade agreements among developed economies that had ambitions beyond trade liberalization (e.g., NAFTA, the European Union). NAFTA, for example, was one of the first major trade agreements to include extensive and legally enforceable environmental provisions, through its side agreement, the North American Agreement on Environmental Cooperation (NAAEC). Another was likely the growing awareness of environmental degradation resulting from mass production, consumption, and international trade. The 1992 Rio Earth Summit, for example, garnered international agreement on issues of environmental degradation, highlighting the urgency of action. Despite the rise in the share of PTAs with environmental provisions, with almost half of PTAs having environmental provisions by 2015, only 10% of those provisions are legally enforceable. The green line in the figure shows that the share of legally enforceable environmental provisions was about 7.7% in 1990 and plateaued at about 10% in 2006 and onward.





PTAs = preferential trade agreements.

Source: World Bank's Deep Trade Agreement Database (Hofmann, Osnago, and Ruta 2017) (accessed 15 November 2023).

Figure 2 shows the overall trend in GVC emissions split over economy pairs within PTAs and without PTAs. Emissions that result from non-PTA based GVC trade is much greater than PTA related emissions throughout the period. While both are steadily increasing, largely because of increased trade in GVCs, PTA related emissions are growing much faster. PTA related emissions were about 10% of total GVC emissions in 1990 and grew to about 35% by 2010 and remained around that share for the rest of the period. For purposes of comparison, Figure 3 shows the trends in the total value of GVC exports for 1990–2015, again decomposed into PTA and non-PTA trade. The growth trajectory of GVC exports show a similar pattern to emissions, although with a more dramatic increase in exports after 2000. In 1990, economy-pairs with a PTA represented about 22% of total GVC exports, but this had increased to 46% by 2015. These two figures highlight the growing relevance of PTA related GVC activities and the emissions embodied in them. Emissions that result from GVCs grew by 3.6% per year, on average, while exports in GVCs grew by 6.5%. The growth rates for pairs not in PTAs were 5.4% for exports and 2.4% for emissions, whereas for pairs in PTAs the numbers were 9.0% for exports and 8.6% for emissions. These differences highlight the growing importance of GVC trade within PTAs, further suggesting that while emissions intensity has been declining for both PTA and non-PTA related GVC trade, the decline has been faster for non-PTA GVC trade.



GVC = global value chain. MT = metric tons, PTA = preferential trade agreement. Source: OECD TeCO2 database (https://www.oecd.org/en/data/datasets/greenhouse-gas-footprint-indicators.html) (accessed 15 November 2023).



Figure 3: Trend in GVC Exports: PTA vs. Non-PTA, 1990–2016

Figure 4 shows the share of total GVC emissions by income level of the exporter, with about 90% of emissions being due to exports of upper-middle and high-income economies. While the combined share remains mostly stable throughout the period, there is a slight increase in the emissions share due to upper-middle income economies over time. The share of lower-middle income economies also showed signs of an increase, with the share rising from 6.2% in 1990 to 14.2% in 2016. At the same time, the share of high-income economies dropped from 51% to 41.5%. Several factors may explain these dynamics. First, middle income economies have increased their integration into GVCs, meaning that they account for a higher share of GVC exports (Figure 5). The share of GVC exports of high-income economies has fallen from 83% in 1990 to 65% in 2016. Second, technological change in more developed economies may have resulted in increased emissions efficiency that has reduced their contribution to emissions. Given imperfect diffusion of technologies, such developments would disproportionately benefit emissions efficiency in developed economies. Third, the changes may also be linked to the pollution haven hypothesis, with developed economies offshoring some of their dirtier activities to developing economies. This can also be considered, therefore, to represent a shift in the structure of GVCs between developed and developing economies.

GVC = global value chain, PTA = preferential trade agreement. Source: Author's calculations using OECD Inter Country Input Output Tables (https://www.oecd.org/en/data/datasets/inter-country-input-output-tables.html) and OECD TeCO2 database (https://www.oecd.org/en/data/datasets/greenhouse-gas-footprint-indicators.html) (accessed 15 November 2023).



Figure 4: Emissions in GVCs by Income Level

GVC = global value chain.

Source: Author's calculations using OECD Inter Country Input Output Tables

(https://www.oecd.org/en/data/datasets/inter-country-input-output-tables.html) and OECD TeCO2 database (https://www.oecd.org/en/data/datasets/greenhouse-gas-footprint-indicators.html) (accessed 15 November 2023).



Figure 5: Exports in GVCs by Income Level

GVC = global value chain.

Source: Author's calculations using OECD Inter Country Input Output Tables

(https://www.oecd.org/en/data/datasets/inter-country-input-output-tables.html) (accessed 15 November 2023).

5. RESULTS

Estimating the Impact of the Presence and Breadth of a PTA On Emissions in GVC Exports

Table 1 reports the main regression results, including results on the impact of the presence and the breadth of PTAs on emissions embodied in GVC exports, and the impact of environmental provisions on GVC-related emissions. The table further reports results using a standard fixed-effects regression approach and using Poisson Pseudo Maximum Likelihood (PPML) methods.

Following much of the recent literature using the gravity equation we estimate a structural gravity model that includes economy-pair and importer-time and exporter-time fixed effects. Results in Table 1 (Column 1) suggest that the existence of a PTA between economy-pairs is associated with an increase in emissions in GVC exports of around 5.2%.² This suggests that even after accounting for exporter, importer and pair characteristics, PTAs are associated with higher emissions embodied in GVC trade. The reasons for this increase are likely related to the impact that PTAs have on GVC trade, with increases in GVC trade because of PTAs increasing emissions embodied in trade. The decomposition results that follow provide more insights.

Results using the measure of PTA breadth—that is, the share of the 52 provisions included in the PTA agreement—instead of PTA presence give similar results (column 2 of Table 1). The statistically significant coefficient estimate of 0.0392 suggests that a move from no PTA to the broadest PTA is associated with an increase in emissions embodied in GVC exports of around 4%. These results suggest that even comprehensive PTAs may increase the emissions in GVC exports, though the effect is relatively small, and we have not accounted for any nonlinearities in the relationship between PTA breadth and GVC-related emissions. To examine this potential nonlinearity, we next consider whether the presence of an environmental provision in PTAs offsets this observed positive impact of PTA presence on GVC-related emissions.

² Calculated as $exp^{(\beta)} - 1$.

	Fixed-Effects Estimator				PPML				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
PTA Dummy	0.0506*** (0.00408)		0.0960*** (0.00721)		0.0481*** (0.0180)		0.0491*** (0.0183)		
PTA Breadth	(, , , , , , , , , , , , , , , , , , ,	0.0392*** (0.00465)	, , , , , , , , , , , , , , , , , , ,	0.0976*** (0.0110)	, ,	0.0433* (0.0256)	,	0.0433* (0.0258)	
Env. Provision		, , ,	-0.0749*** (0.00783)	-0.0655* ^{**} (0.0100)	-0.0544*** (0.0181)	-0.0455** (0.0210)	-0.0554*** (0.0183)	-0.0456** (0.0212)	
Constant	7.324*** (0.000371)	7.326*** (0.000298)	`7.324*** [´] (0.000360)	7.326*** (0.000296)	ζ <i>γ</i>	χ γ	, , , , , , , , , , , , , , , , , , ,	ζ <i>γ</i>	
Economy Pair FE Importer-Time, Exporter-Time FE	Yes Yes	Yes Yes	Yes Yes	Yes Yes	Yes Yes	Yes Yes	Yes Yes	Yes Yes	
Observations R-squared	751,937 0.995	751,937 0.995	751,937 0.995	751,937 0.995	751,937 0.995	751,937 0.995	752,837 0.995	752,837 0.995	

Table 1: Estimating the Impact of the Presence and Breadth of a PTA onEmissions in GVC Exports

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

GVC = global value chain, PTA = preferential trade agreement.

Source: Author's calculations.

Estimating the Impact of the Presence of an Environmental Provision in PTAs on Emissions in GVC Exports

To consider the role of the presence of an environmental provision, columns 3 and 4 of Table 1 introduce the dummy variable capturing the presence of an environmental provision. Qualitatively, the coefficients on the PTA variables remain positive and significant, though the size of the coefficients is somewhat larger than in columns 1 and 2.

Focusing on the coefficient on the environmental provision dummy variable we see that coefficients are negative and significant. Coefficients on the environmental provision dummy are similar when included alongside the PTA dummy and PTA breadth variable. In the case of the PTA dummy, the coefficient on the environmental provision variable suggests that the presence of an environmental provision is associated with a reduction in GVC-related emissions of around 7.2%, while when including the PTA breadth variable an environmental provision is associated with a reduction in GVC-related emissions of around 7.2%, while when including the PTA breadth variable an environmental provision is associated with a reduction in GVC-related emissions of 6.3%. While these estimated reductions are lower than the increase in emissions associated with the presence or breadth of a PTA, the effects are substantial. In the case of the PTA dummy, the estimated reduction in GVC-related emissions because of the presence of an environmental provision is around 72% of the increase in GVC-related emissions associated with the presence of a PTA. These findings suggest that while PTAs facilitate trade and increase emissions, environmental provisions within these agreements play a critical role in mitigating these effects.

Estimating Effects of PTAs and Environmental Provisions Using PPML

The results in the first four columns of Table 1 use fixed effects structural gravity models and provide support for the view that even as PTAs increase GVC-related emissions traded between PTA partners, the presence of an environmental provision in those agreements can offset this increase. The use of PPML methods have become an increasingly popular way of dealing with the presence of zero trade flows and heteroscedasticity (Santos and Tenreyro 2006). For our purpose, there are good reasons for avoiding using PPML. The dependent variable in our analysis, the emissions embodied in GVC exports, is constructed using multiregional input-output tables and methods. In principle, there should be no zero observations when constructing these data, with any zero values being the result of missing observations rather than zero trade flows. Including the zero values, therefore, is not recommended. In addition, the approach that we adopt relies on a decomposition of GVC-related emissions into a scale and intensity effect, with the intention being to decompose the effect of PTAs and environmental provisions into an effect working on these two terms. This can be achieved using a linear model, such as OLS or fixed effects regression models, but the decomposition breaks down for the nonlinear PPML model.

Despite these arguments, it is useful to examine whether results obtained using the standard fixed-effects model also hold when using the alternative PPML approach. The final four columns of Table 1, therefore, report results using the PPML estimator. The results when using PPML include both economy-pair and importer-time and exporter-time fixed effects. Columns 5 and 6 of Table 1 report results from models estimated on the same set of observations as used in the first four columns, thus avoiding including missing values in the regression model, while the final two columns include the full set of observations. The results are consistent and indicate a positive impact of PTA presence and PTA breadth on GVC-related emissions and a negative impact of an environmental provision. Focusing on columns 5 and 6, the results suggest that the presence of a PTA is associated with an increase in GVC-related emissions of about 4.9%, with the broadest PTA associated with an increase of 4.4%. Conversely, the presence of an environmental provision is associated with a reduction in GVC-related emissions of between 4.4% and 5.3% depending on the specification. These results are thus consistent with those reported using standard fixed effects models, although in the case of PPML the presence of an environmental provision tends to more than offset the increase in GVC-related emissions associated with the presence of a PTA. Given the challenges of the PPML for our approach, in the rest of the paper we focus on standard fixed-effects regression models.

Do Legally Enforceable Environmental Provisions Have Differential Effects on GVC Exports?

While the above results show that the presence of environmental provisions has a consistent negative effect on emissions, we can further assess whether the enforceability of such provisions causes a differential impact. Table 2 extends the previous analysis using an interaction between the environmental provision variable and whether the provision is legally enforceable. For comparison the table includes the results from columns 3 and 4 of Table 1.

Focusing on the results on the environmental provision variable, the first thing to note is that the coefficient on the combined environmental provision variable lies between the coefficients for enforceable and non-enforceable provisions as would be expected. When included alongside the PTA dummy, the results indicate that environmental provisions that are not legally enforceable are associated with a decrease in GVC- related emissions of about 9%, while provisions that are legally enforceable are associated with a 6% reduction in GVC-related emissions. The two coefficients are significantly different. This is interesting because the non-enforceable provisions seem to be more effective in reducing emissions. This may be because non-enforceable provisions signal a commitment to environmental standards or because they are backed by international pressure or norms that encourage compliance even without legal enforcement. While legally enforceable provisions are still effective, the smaller magnitude might suggest that their impact is more dependent on how strictly they are enforced or on the specific legal and institutional frameworks of the economies involved.

Including the two environmental provision variables alongside the PTA breadth variable gives results that are qualitatively similar. Non-legally enforceable PTAs are associated with a 7.1% decrease on GVC-related emissions, and legally enforceable ones with a 5.8% reduction. While the impact is slightly smaller than those in column 2, the results still suggest that both enforceable and non-enforceable provisions can be effective in reducing emissions. In this case, there are no significant differences in the size of the two coefficients. Given challenges in enforcing environmental provisions related to differences in environmental standards across various jurisdictions, as well as having effective legal mechanisms that allow enforcement, the result that non-enforceable provisions in PTAs are associated with reductions in GVC-related emissions provides some reassurance and support for the signaling role of environmental provisions.

	(1)	(2)	(3)	(4)
PTA Dummy	0 0960***	0 0963***		
	(0.00721)	(0.00721)		
PTA Depth	(0.001 = 1)	(0.001 = 1)	0 0976***	0 0957***
			(0.0110)	(0.0110)
Env. Provision	-0.0749***		-0.0655***	(0.0110)
	(0.00783)		(0.0100)	
Env. Provision (Not Legally	()	-0.0859***	(******)	-0.0686***
Enforceable)				
,		(0.00873)		(0.0103)
Env. Provision (Legally Enforceable)		-0.0579***		-0.0568***
		(0.00856)		(0.0111)
Constant	7.324***	7.324***	7.326***	7.326***
	(0.000360)	(0.000362)	(0.000296)	(0.000296)
Year FE	No	No	No	No
Economy FE	Yes	Yes	Yes	Yes
Importer-Time, Exporter-Time FE	Yes	Yes	Yes	Yes
Observations	751,937	751,937	751,937	751,937
R-squared	0.995	0.995	0.995	0.995

Table 2: Regression Results Distinguishing between Legally Enforceable and
Non-enforceable Environmental Provisions in PTAs

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

PTAs = preferential trade agreements.

Source: Author's calculations.

Decomposing the Effect of PTAs and Environmental Provisions into a Scale and Intensity Effect

After identifying an effect of PTAs and environmental provisions in PTAs on GVC-related emissions, we move to assess the scale and intensity effect by decomposing GVC-related emissions. Results are reported in Table 3, and the analysis focuses on results using PTA breadth rather than the PTA dummy for reasons of brevity. In this table, models 1 and 4 shows the effect on GVC-related emissions and are replicated from Table 1 and Table 2 above, with models 2 and 5 reporting results with GVC-related exports as the variable (capturing the scale effect) and columns 3 and 6 results when GVC-related emissions intensity is the dependent variable (capturing the emissions intensity effect).

In terms of the scale effect, results from model 2 suggests that a shift from no PTA to the broadest PTA is associated with a 6.7% increase in GVC exports, while the presence of an environmental provision is associated with 3.9% reduction in GVC exports. The corresponding results for the intensity effect in model 3 show that a shift to the broadest PTA is associated with a 3.29% increase in emission intensity of GVCs and the presence of environmental provisions in PTAs is associated with a 2.73% reduction. Using these results and those from model 1 it is possible to decompose the overall effect of PTAs and environmental provisions in PTAs into a scale and intensity effect. The results suggest that about 67% (i.e., 0.0652/0.0976) of the overall effect of PTA breadth on GVC-related emissions is due to an increase in the scale of GVC exports in response to a PTA, with the remaining share a result of an increase in emissions intensity, likely because of a change in the structure of GVC exports toward more emissions intensive sectors, such as manufacturing. The scale effect is also found to account for most of the overall effect of the environmental provision (-0.0387/-0.0655=0.59), with the intensity effect accounting for the remaining 41% of the overall effect. Environmental provisions thus

seem to work by reducing the level of GVC exports between trade partners, but also by reducing the emissions intensity of GVC-related exports. This latter result would be consistent with environmental provisions shifting the structure of GVC exports toward cleaner sectors. The results do not preclude the possibility of environmental provisions also resulting in increased technology diffusion that improves emissions intensity, but we cannot distinguish between the structural and technology effect in our results.

Results when splitting between enforceable and non-enforceable environmental provisions are qualitatively similar to the results in models 1–3, with the presence of environmental provisions—legally enforceable or not—associated with lower GVC exports and the emissions intensity of those exports. The results suggest that the size of the coefficient for non-enforceable environmental provisions is larger (in absolute value) than that for enforceable provisions in the case of emissions intensity, a difference that is statistically significant. For GVC exports there is no significant difference in coefficients between non-enforceable and enforceable environmental provisions, though in this case the coefficient is larger (in absolute value) for enforceable provisions.

There are differences in the importance of the scale and intensity effects between enforceable and non-enforceable provisions. For non-enforceable provisions, the scale and intensity effect account for a similar share of the overall effect. The scale effect accounts for 53% of the reduction in GVC-related emissions from an environmental provision, and the intensity effect accounts for 47%. In the case of enforceable provisions, however, the scale effects accounts for 79% of the overall reduction in GVC-related emissions, whereas the intensity effect accounts for 21%. The results suggest that enforceable environmental provisions have a much stronger impact on overall emissions by reducing GVC exports but are less successful in reducing emissions intensities.

	(1) Emissions	(2) Exports	(3) Emissions	(4) Emissions	(5) Exports	(6) Emissions
			Intensity			Intensity
PTA Depth	0.0976*** (0.0110)	0.0652*** (0.0104)	0.0324*** (0.00486)	0.0957*** (0.0110)	0.0666*** (0.0104)	0.0291*** (0.00482)
Env. Provision	-0.0655*** (0.0100)	-0.0387*** (0.00946)	-0.0269*** (0.00448)			
Env. Provision (Not Legally Enforceable)	()	, , , , , , , , , , , , , , , , , , ,	,	-0.0686***	-0.0364***	-0.0322***
,				(0.0103)	(0.00971)	(0.00462)
Env. Provision (Legally Enforceable)				-0.0568***	-0.0450***	-0.0118**
				(0.0111)	(0.0103)	(0.00488)
Constant	7.326***	14.30***	-6.977***	7.326***	14.30***	-6.977***
	(0.000296)	(0.000263)	(0.000132)	(0.000296)	(0.000263)	(0.000132)
Year FE	No	No	No	No	No	No
Economy FE	Yes	Yes	Yes	Yes	Yes	Yes
Importer-Time, Exporter-Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	751,937	751,937	751,937	751,937	751,937	751,937
R-squared	0.995	0.996	0.995	0.995	0.996	0.995

Table 3: Decomposing the Effect of PTAs and Environmental Provisions on GVC Related Emissions

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

GVC = global value chain, PTA = preferential trade agreement.

Source: Author's calculations.

Impacts of PTAs and PTA Provisions on Emissions in GVC Exports by Exporter's Income Level

We extend the analysis by assessing whether the magnitude of the overall scale and intensity effect depends on the income level of the exporter. By examining the effects of PTAs and environmental provisions on emissions in GVC trade by income group, we are interested in understanding whether the burden and benefits of these show heterogeneous effects and whether they fall on specific economy groups. One argument that we consider relevant is the idea that since low-income countries tend to have lower bargaining power in negotiations over trade agreements, they may be required to accept more stringent environmental standards in trade agreements than they would prefer. In contrast, in high-income economies environmental stringency in trade agreements may not differ substantially from that already in existence. A further argument is that given comparative advantage low-income countries may tend to specialize in more emissionintensive activities in GVCs and, therefore, their exports may be disproportionately affected by the environmental provisions in PTAs. Conversely, such provisions may favor low-income countries by enabling the diffusion of green technologies that can reduce emissions traded in GVCs. While it is not straightforward to distinguish between these different hypotheses, combined they provide a strong motivation to consider the possibility of heterogeneous effects of environmental provisions in PTAs by income level.

Results are reported in Table 4, with three sets for each income group, these being when the dependent variable is: (i) the logged level of GVC-related emissions; (ii) the log of GVC exports; and (iii) the log of the emissions intensity. The results for low-income countries indicate that a shift from no PTA to the broadest PTA is associated with an increase in GVC-related emissions of 58%, and two-thirds of this is due to the scale effect and the rest is due to the intensity effect. The effect of an environmental provision is to reduce the emissions embodied in PTAs by about 20%, substantially lower than the overall effect of the deepest PTA. This reduction works through both the scale and intensity effect, with the scale effect accounting for around 59% of the overall effect. The results thus suggest that environmental provisions seem to be effective in mitigating the effects of PTAs in low-income countries through regulations that limit the export of emission intensive goods (scale effect) and possibly encouraging cleaner technology that reduces emissions intensity (intensity effect).

Results for lower-middle and upper-middle income economies present some differences from those for low-income countries and relative to each other. The estimated effect of PTA breadth is found to be around one quarter the size of that for low-income countries, with results for both the lower-middle and upper-middle income groups suggesting an increase in GVC-related emissions of about 11%. While in the case of the lower-middle income group this is driven by the intensity effect (accounting for 57% of the increase) in the case of the upper-middle income group the scale effect dominates (accounting for 81% of the change). In other words, a PTA is associated with higher emissions in both groups, which for the lower-middle income group is mainly due to an increase in emissions intensity, perhaps reflecting a shift in the structure of GVC trade of this group toward dirtier sectors, while in upper-middle income economies is mainly due to an increase in the scale of exports in GVCs.

Whereas coefficients on the environmental provision variable are negative for the lowermiddle and upper-middle income groups in the case of GVC-related emissions, the coefficient is not significant for the lower-middle income group. This is despite a significant negative impact of an environmental provision on emissions intensity. Results for uppermiddle income economies suggest that an environmental provision is associated with a reduction in GVC-related emissions of about 10%, with four-fifths of this a result of reductions in the scale of GVC exports and the remaining fifth being due to emissions intensity.

Turning finally to high-income economies, the results suggest a relatively small effect of PTAs on GVC-related emissions. The presence of the broadest PTA is associated with an increase in GVC-related emissions of about 6%, driven by an impact on the scale of GVC exports. A small negative effect of environmental provisions is also found, with the presence of an environmental provision estimated to reduce GVC-related emissions by about 4%, and the effect driven entirely by the scale effect.

by meenic Group									
	(1)	(2)	(3)	(4)	(5)	(6)			
VARIABLES	Emissions	Exports	Emissions	Emissions	Exports	Emissions			
			Intensity			Intensity			
	Lov	w Income Exporte	rs	Lower-M	Lower-Middle Income Exporters				
PTA Breadth	0.457***	0.304***	0.153***	0.112***	0.0492*	0.0628***			
	(0.0579)	(0.0474)	(0.0292)	(0.0279)	(0.0256)	(0.0122)			
Env. Provision	-0.215***	-0.126***	-0.0889***	-0.0406	0.0103	-0.0509***			
	(0.0350)	(0.0296)	(0.0200)	(0.0261)	(0.0252)	(0.0106)			
Constant	5.285***	12.55***	-7.268***	6.770***	13.62***	-6.847***			
	(0.00114)	(0.000921)	(0.000607)	(0.000498)	(0.000430)	(0.000239)			
Observations	99,122	99,122	99,122	202,777	202,777	202,777			
R-squared	0.991	0.991	0.991	0.994	0.994	0.990			
	Upper-N	High Income Exporters							
PTA Breadth	0.111***	0.0905***	0.0201**	0.0553***	0.0507***	0.00464			
	(0.0228)	(0.0224)	(0.0101)	(0.0118)	(0.0115)	(0.00458)			
Env. Provision	-0.103***	-0.0835***	-0.0200**	-0.0448***	-0.0502***	0.00538			
	(0.0213)	(0.0206)	(0.00909)	(0.0111)	(0.0106)	(0.00452)			
Constant	7 .798** [*]	Ì4.15** [*]	-6.351*** [´]	8.308** [*]	Ì5.67** [*]	-7.362***́			
	(0.000560)	(0.000528)	(0.000259)	(0.000674)	(0.000617)	(0.000267)			
Observations	188,647	188,647	188,647	247,872	247,872	247,872			
R-squared	0.994	0.995	0.997	0.997	0.997	0.996			

Table 4: Regression Results on the Decomposition of GVC-Related Emissions
by Income Group

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

GVC = global value chain, PTA = preferential trade agreement.

Source: Author's calculations.

These results provide some interesting insights, consistent with the set of arguments made above. Both the breadth of a PTA and an environmental provision in those PTAs have stronger impacts in low-income countries. As such, low-income countries benefit to a larger extent from the presence of a PTA through its effect on the scale of GVC-related exports, but they also see bigger reductions in GVC-related emissions due to an environmental provision in PTAs. These bigger reductions would be consistent with arguments so far in this paper, stressing the limited bargaining power that low-income countries have in PTA negotiations and the possibility that the effects of environmental provisions are large for low-income countries because they tend to specialize in

emissions intensive activities. It could also be that environmental provisions help offset the lack of domestic environmental regulations and promote the adoption of cleaner technologies, with the technology effect also more profound relative to high-income economies due to them being behind the technology frontier. At the other extreme high and upper-middle income economies see smaller increases in GVC-related emissions in response to a PTA and smaller reductions in such emissions in response to an environmental provision in those PTAs. It is interesting that these effects are driven almost entirely by scale effects, with at best a small role for emissions intensity. One reason for this may be because high income exporters are likely more service-oriented and more specialized in high-value added activities in both upstream and downstream sectors³, activities that are less reliant on emissions-intensive production. The narrow role of the intensity effect could be due to the limited possibilities for these economies to benefit from green technologies made available through GVCs. While it is not possible to distinguish these possible effects in our analysis, they provide important directions for future research.

Introducing Leads and Lags into the Structural Gravity Model

As a final robustness test, Table 5 introduces three-period leads and lags of the PTA and environmental provision variable. Most PTAs are negotiated over a long period and once agreed have phase-in periods of 5 to 10 years. An extended negotiation period could lead to anticipatory effects of firms, with the result that effects of the agreement could be observed prior to it coming into force. Conversely, the phase-in period could imply that the full effects of the agreement may take time to accrue, especially if relevant provisions do not enter into force immediately. The introduction of leads and lags is intended to account for these potential anticipatory and phase-in effects.

Results in Table 5 indicate the possibility of both contemporaneous but also anticipatory effects of the PTA breadth variable on GVC-related emissions (column 4). When including leads and lags at the same time (columns 7–9), there is also some evidence of a lagged effect of the PTA variable. The combined effect of these is roughly the same size as that found when including the contemporaneous PTA variable only. Both the lagged and anticipatory effects appear to be driven by an effect working on the intensity of emissions in GVCs.

No evidence of a lagged effect on emissions is found in the case of the environmental provision variable (column 1), though this reflects an offsetting positive effect on GVC-related exports (column 2) and negative effect on emissions intensity (column 3). There is evidence of an anticipatory effect (column 4), however, with the combined effects again similar to those when including the contemporaneous variable only. The anticipatory effect is driven by the scale effect, consistent with the argument that importing economies turned away from firms in exporting partners where an environmental provision in a PTA was anticipated prior to the agreement and environmental provision entering into force.

³ These usually imply R&D, and service sectors like marketing, finance, etc. They are far less emissions intensive than manufacturing and perhaps not always affected by environmental provisions in PTA.

Overall, the inclusion of leads and lags provides some additional insights into the dynamics of the response to the presence of a PTA and environmental provision, though also providing a great deal of consistency regarding the overall direction and magnitude of the effect of these on GVC-related emissions.

	(1) Emissions	(2) Exports	(3) Emissions	(4) Emissions	(5) Exports	(6) Emissions	(7) Emissions	(8) Exports	(9) Emissions
			Intensity			mensity			Intensity
PTA Breadth	0.0691*** (0.00949)	0.0548*** (0.00898)	0.0143*** (0.00453)	0.0892*** (0.00971)	0.0604*** (0.00846)	0.0288*** (0.00477)	0.0560*** (0.00755)	0.0427*** (0.00707)	0.0133*** (0.00351)
PTA Breadth (lag)	0.00152 (0.0101)	-0.0214** (0.00953)	0.0229*** (0.00491)				0.0263*** (0.0101)	-0.00533 (0.00873)	0.0316*** (0.00537)
PTA Breadth (lead)				0.0367***	0.0237***	0.0130***	0.0142*	0.00786	0.00638*
Env. Provision	-0.0645***	-0.047***	-0.0175***	(0.00909) -0.0402*** (0.00853)	(0.00784) -0.0153** (0.00753)	(0.00401) -0.0248*** (0.00437)	(0.00780) -0.0447*** (0.00670)	(0.00701) -0.0264*** (0.00620)	(0.00375) -0.0182*** (0.00337)
Env. Provision (lag)	0.0132	0.0265***	-0.0133***	(0.00000)	(0.00733)	(0.00437)	0.00358	0.0278***	-0.0242***
Env. Provision	(0.00907)	(0.00855)	(0.00461)	-0.0487***	-0.0318***	-0.0169***	(0.00905) -0.0254***	(0.00790) -0.0185***	(0.00501) -0.00694**
Constant	7 376***	1/ 30***	_7 018***	(0.00893)	(0.00763)	(0.00393)	(0.00727) 7 321***	(0.00660)	(0.00340) -6 919***
Constant	(0.000332)	(0.00030 4)	(0.000154)	(0.000339)	(0.000290)	(0.000156)	(0.000368)	(0.000324)	(0.000183)
Economy FE Importer-Time, Exporter-Time FE	Yes Yes	Yes Yes	Yes Yes	Yes Yes	Yes Yes	Yes Yes	Yes Yes	Yes Yes	Yes Yes
Observations R-squared	668,949 0.996	668,949 0.996	668,949 0.995	668,270 0.996	668,270 0.997	668,270 0.996	585,282 0.997	585,282 0.997	585,282 0.997
Debuet step	ala		***0	01 ** 0 0	F * 0 1				

Table 5: Regression Results Including Lags and Leads of the PTA and Environmental Provision Variables

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

PTA = preferential trade agreement.

Source: Author's calculations.

6. DISCUSSION AND CONCLUSION

The ever-increasing importance of GVCs as a source of development has spurred numerous debates on the environmental consequences of fragmented production. International trade related CO_2 emissions have been on the rise, prompting us to consider the emissions embodied in value-added trade. PTAs have proved to be important drivers of GVC trade, and the coverage of nontrade provisions in PTA design has increased sharply. Environmental provisions have been introduced with the aim of mitigating some of the harmful consequences of trade either through restrictive or liberal practices. This paper addresses whether such provisions impact on CO_2 emissions in GVCs, and the role of legal enforcement in mediating this relationship.

The results show that PTAs increase GVC-related emissions, an effect driven by scale and structure effects of PTAs—i.e., higher trade volumes between PTA partners as well as a shift toward more emissions intensive sectors. However, the inclusion of environmental provisions offsets most of this increase, an effect that works mainly through the scale effect and that likely reflects the role of trade restrictive environmental provisions. This result resonates with the literature on the scale effect, which posits that environmental provisions can reduce emissions by restricting trade in carbon-intensive goods. By reducing emissions intensity, environmental provisions in PTAs also appear to have both structure and technology effects, shifting production in GVCs toward cleaner sectors and potentially encouraging technology diffusion. With the adopted framework, it is not possible to identify the relative importance of these two drivers.

Both enforceable and non-enforceable environmental provisions have negative effects on emissions, with non-enforceable provisions showing greater efficacy. This unexpected result could be attributed to the flexibility such provisions offer, allowing economies to tailor environmental policies to local contexts, and so encouraging voluntary compliance and technological upgrading, as supported by the Porter Hypothesis (Mealy and Teytelboym 2022; Porter and van der Linde 1995). This suggests that non-enforceable provisions may be more conducive to long-term emissions reductions by promoting innovation and capacity building, especially in lower-income economies (Baghdadi, Martínez-Zarzoso, and Zitouna 2013).

When decomposing the effects by scale and intensity, the scale effect dominates for both PTA depth and environmental provisions, indicating that emissions reductions can be more effectively achieved by focusing on curbing the volume of carbon-intensive trade. Legally enforceable provisions are more effective in controlling emissions via the scale effect, limiting carbon-intensive trade, whereas non-enforceable provisions primarily reduce emissions through the intensity effect, encouraging technological advancements and structural shifts. These findings align with the literature, which highlights that non-binding environmental regulations can foster gradual improvements in environmental standards (Downs, Rocke, and Barsoom 1996; Sprinz and Vaahtoranta 1994).

The analysis by income level offers additional insights. In low-income countries, the scale effect predominates, reflecting their engagement in emissions-intensive upstream activities, similar to findings by Kolcava, Nguyen, and Bernauer (2019). In contrast, lowermiddle income economies show a more pronounced intensity effect, driven by technological upgrading in emissions-intensive manufacturing, in line with research indicating that technology transfer can be critical for emissions reductions in these economies (Milewicz et al. 2018; Zhang et al. 2023). Upper-middle income economies, which are often engaged in complex manufacturing, see larger scale effects due to restrictions on high-emission sectors like heavy manufacturing. These economies are most likely engaged in heavy manufacturing and more complex GVC activities. If environmental provisions limit the trade in these products, then it should decrease the export volume explaining the scale effect. Finally, in high-income economies, emissions reductions are achieved almost exclusively through the scale effect, as these economies already employ advanced technologies and engage in high-value-added production with stringent environmental regulations (Bastiaens and Postnikov 2017). The large-scale effect is probably because high-income economies tend to be quite diversified in their GVC activities (upstream sectors like R&D or downstream sectors from high-tech manufacturing to financial services).

The effectiveness of environmental provisions in PTAs, particularly non-enforceable types, is an encouraging outcome for trade policy. Non-enforceable environmental provisions allow economies greater flexibility in implementation while fostering voluntary cooperation and technology sharing, making them more palatable for a broader range of economies, especially those at varying stages of development (Morin, Dür, and Lechner 2018). These provisions can promote sustainable practices in GVCs without imposing high compliance costs or risking trade disruption. In fact, the ease of codifying non-enforceable provisions suggests they can be more widely adopted, potentially driving global convergence on environmental standards, especially in sectors integrated into GVCs where strict regulations may be more challenging to implement. The gradual adoption of greener practices encouraged by non-binding provisions aligns with the Porter Hypothesis.

One shortcoming of current research on environmental provisions in PTAs is the lack of granular data to precisely identify which aspects of these provisions are most effective. The diversity in the types of goods and processes covered by different PTAs makes it difficult to discern whether certain provisions—such as those targeting specific pollution-intensive sectors or those encouraging technology transfer—drive the observed reductions in emissions. Also, little is known about the differential impacts of these provisions based on income levels. Low-income countries may face more significant challenges in implementing environmental standards because of resource constraints, while high-income economies may benefit more from such provisions because they have better regulatory capacity and access to cleaner technologies. Another consideration is the potential trade diversion resulting from environmental provisions in PTAs.

The analysis does not allow us to determine whether the reduction in emissions between PTA partners results in increased emissions with non-PTA partners or higher domestic emissions. Consequently, it remains unclear whether these provisions are leading to a net increase or decrease in global emissions. Future research could address these gaps by conducting case studies on different PTAs to examine how their specific environmental provisions impact trade flows, exports, and emissions for member economies. If more detailed data on the structure and enforcement of environmental provisions becomes available, it could help isolate which provisions are most effective, further informing policy makers on how to design environmental provisions that maximize environmental benefits while minimizing economic costs.

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Do Environmental Provisions in Preferential Trade Agreements Reduce Emissions Traded in Global Value Chains?

This paper examines whether preferential trade agreements (PTAs) increase emissions embodied in trade, further considering whether environmental provisions in PTAs affect this relationship. The results suggest PTAs are associated with increased emissions embodied in trade, with this effect mainly because of increased trade between PTA partners. The presence of an environmental provision in PTAs, however, mitigates this effect, with environmental provisions reducing both the scale of trade and the emissions intensity of that trade.

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